2.3 Intelligent Engine Systems
2.3.3.2 Advanced Film Cooling Techniques

Dunn (Ohio State) & Mavris (Ga Tech.)

Science & Technology Objective(s):

- Obtain a detailed film cooling data base under laboratory controlled conditions for a state-of-the-art turbine stage. All of the relevant design parameters must be duplicated for this measurement program.

Collaborations:

- Government - NASA Glenn Research Center
- Industry - Honeywell, General Electric Aircraft Engines, Pratt/Whitney
- URETI - OSU & Georgia Tech.
- Synergism - Honeywell & GEAE programs

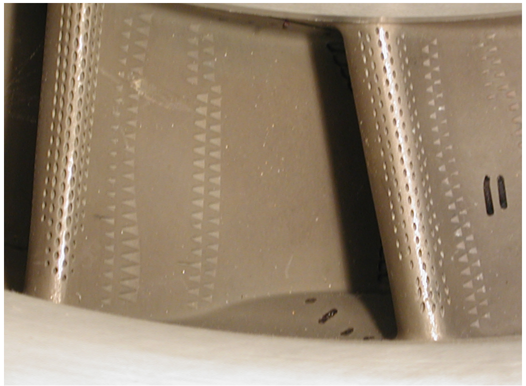
Proposed Approach:

- Permission obtained to use TFE 1042 turbine stage.
- Complete advanced instrumentation development.
- Complete rig assembly and verification.
- Perform measurement program, data reduction and analysis.

NASA & Air Force Relevance/Impact:

- Film cooling data set for full-stage rotating turbine does not presently exist.
- Will have significant impact on development of film cooling modeling and CFD code development.

Photograph of Film Cooled Vane & Blade



Milestones/Accomplishments:

- Complete development of Kapton gauge instrumentation
- Install Kapton gauges on vanes & blades
- Complete rig assembly & cooling system verification
- Determine film cooling effectiveness for:
  - Engine values of Tc/Tg, Tc/Tw, & Tw/Tg; M, DR
  - Engine design corrected speed & Flow Function
- Measurements to include heat transfer, gas temperatures, and relevant pressures
- Complete analysis of experimental results
- Initiate development of film cooling macro model

Georgia Institute of Technology · The Ohio State University · FAMU Florida A&M University · CWRU

Background

- The Ability to Design and Control Efficient Film-Cooling Schemes is Essential for Development of Advanced Engines
  - Existence of applicable experimental results would permit design of improved, and controllable, film cooling systems
- A Major Limitation Within the Industry is the the Absence of Experimental Results for Flow Conditions Associated with Realistic Turbine Operating Conditions
  - A data set for a fully-cooled turbine stage does not exist
  - Current state-of-the-art permits this innovative experiment
  - Realistic data set is essential for development of macro model
  - Cascade data for blade have been shown to be not applicable for rotating turbine -- all turbines of interest to the industry rotate

Proposed Approach

- Utilize the Existing Honeywell TFE 1042 Fully-Cooled HPT Turbine Stage and the Associated Rig Hardware
  - Honeywell has agreed to share vane & blade coordinates with other U.S. engine companies
- Complete Ongoing Instrumentation Development, Rig Assembly, and Verification Effort
- Initial research effort will be performed in two phases:
  - With cooling system as designed by manufacturer
  - With miniature control/feedback to selectively control cooling flow
- Experimental Results Will Have Significant Impact on Development of Film Cooling Modeling and CFD Code Development

2.3 Intelligent Engine Systems

2.3.3.1 Loss Control Using Trailing Edge Injection

Dunn (Ohio State) & Sankar (Ga Tech)

Science & Technology Objective(s):

- Determine how trailing edge injection can be effectively used to change airfoil configuration.
- Demonstrate that wake deficit can be reduced.
- Reduce importance of trailing edge shock.

Collaborations:

- Government - U.S. Air Force and NASA
- URETI - OSU and Georgia Tech
- Industry - Rolls Royce America
- Synergism with existing programs - Honeywell film cooling and General Electric film cooling programs

Proposed Approach:

- CFD analysis to design experimental program
- Incorporation of additional instrumentation in VBI rig
- Perform measurement program
    - Over range of injection parameters
    - At different Mach number & vane/blade spacing

NASA and Air Force Relevance/Impact:

- Potential for reducing wake losses and improving performance.
- Potential for reducing shock losses and thus reduced HCF & improved performance.

VBI vane with trailing edge injection:

Milestones/Accomplishments:

- Complete design of experiment using existing CFD and modeling capability
- Experimentally verify desired injection mass flow rates and temperature and pressure conditions.
- Incorporate additional instrumentation in VBI rig.
- Perform measurement program.
- Work with modeling and CFD investigators at Georgia Tech to incorporate results into design system.

Background

- Trailing Edge Injection can Potentially be Used to Alter Airfoil Configuration
- CFD Indicates that this Technique Should Make it Possible to Reduce Wake Deficit
- Should Also be Possible to Reduce Importance of Trailing Edge Shocks for Transonic Turbine Stages
- Allison Vane Blade Interaction (VBI) Rig Available at OSU GTL & is an Excellent Vehicle for these Studies

Proposed Approach

- Configure the Trailing Edge Slots with a MEMS Device so that
- Vectoring of the Ejected Gas Effectively Changes the Physical
  - Can significantly influence the resulting interaction between
  - System will allow discharge of vectored and modulated gas
- Measurements would be Performed Over a Range of Mach
- Georgia Tech and OSU Would Collaborate to Model the

2.1.4 High Fidelity Design Tool Development
2.1.4.3 Aero elastic Response Prediction Tool Development

Dunn (Ohio State) & Mavris (Ga Tech)

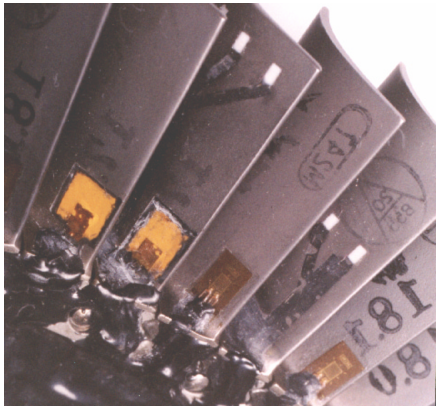
Science & Technology Objective(s):
- Provide relevant experimental results for aero elastic response for two very different engines.
- Provide experimental results (& assistance) for incorporation into Georgia Tech design system code.

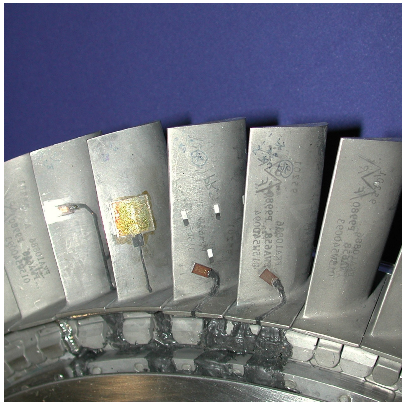
Collaborations:
- Government - NASA Glenn and USAF
- URETI - OSU and Georgia Tech
- Industry - Honeywell, R-R America, & Pratt/Whitney
- Synergism with existing programs - Previous GUIde program/NASA and Air Force Program/Air Force

Proposed Approach:
- Integrate existing TFE 731-2 results
- Obtain additional TFE 731-2 results from existing data base
- Perform measurement program for modern vane less counter-rotating (VCC) turbine stage.

NASA & Air Force Relevance/Impact:
- TFE 731-2 data set is unique. Impact is on aero elastic modeling and CFD code development.
- Experimental results for modern VCC stage significantly expands modeling & code capability.

TFE 731-2 blade (l) & Modern blade (r)





Milestones/Accomplishments:
- Transfer existing TFE 731-2 results to Georgia Tech. and incorporate results into structural model for forced response. Industry and NASA are currently comparing initial results with models and CFD codes.
- Mine additional information from TFE 731-2 data set and incorporate results into structural model by working with Georgia Tech, industry, NASA, and Air Force.
- Perform measurement program for modern VCC engine stage. Work with industry and government to determine validity of existing models and CFD codes.

Background

- Modern turbine Designs are Characterized by Large Stage Pressure Ratios and Highly Loaded Airfoils
- These Designs are Susceptible to Aero Elastic Excitation or High-Cycle-Fatigue (HCF)
  - This event is poorly understood, and has become a source of concern for these designs,i.e., Air Force 8th National HCF Conference (April 2003)
- State-of-the-art Experimental Techniques have Progressed Significantly
  - Useful experimental information regarding HCF can now be affordably obtained with sufficient accuracy to interest the design community
  - Past experience has demonstrated that measurements can be accomplished
    - TFE 731-2 , YF-120, XTE-66

Proposed Approach

- Honeywell TFE 731-2 data Obtained @ OSU is Currently Available to U.S. Industry
  - Older machine that encountered unexpected HCF difficulties
  - Additional significant information can be mined from data set
- Some Modeling and CFD Related to this Data Set Has Been Reported and is Ongoing
  - Honeywell and Rolls-Royce America
  - NASA Glenn and the University of Toledo
- Modern VCC Turbine Instrumented @ OSU GTL
- Fully instrumented with miniature Kulite pressure transducers and with strain gauges
  - This design is no longer being used by P/W, but excellent vehicle for CFD development
  - Need U.S. Air Force and industry permission to use hardware